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A REVIEW OF PROGRESS IN THE DEVELOPMENT OF A ROLLING RESISTANCE TRAILER

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by

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ABSTRACT

The reduction of rolling resistance of mine haulage roads has been identified as a means of significantly reducing the operating costs of many mines. For this reason CANMET has been involved in the development of a trailer which is capable of measuring the rolling resistance of mine haulage roads. This paper reviews the progress that has been made in the development of this trailer and the associated instrumentation and data acquisition systems.

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APERÇU DES PROGRÈS RÉALISÉS AU NIVEAU DU DÉVELOPPEMENT D'UNE REMORQUE CAPABLE DE MESURER LA RÉSISTANCE AU ROULAGE

par

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RÉSUMÉ

La réduction de la résistance au roulage sur les chemins de service des mines a été identifiée comme un des moyens à prendre pour réduire considérablement les coûts d'exploitation de plusieurs mines. C'est pour cette raison que le CANMET a été intéressé à participer au développement d'une remorque capable de mesurer la résistance au roulage sur les chemins de service des mines. Ce rapport donne donc un aperçu des progrès réalisés dans le cadre du développement de cette remorque, des appareils utilisés et des systèmes d'acquisition de données.

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1.0 INTRODUCTION

The Surface Mining Laboratory has commissioned the construction of a vehicle capable of measuring the rolling resistance of mine haul roads. This equipment has now been delivered to CANMET for field trials. This paper provides a description of the current state of development of the vehicle and how the vehicle will be tested to ensure that it is capable of accurately measuring rolling resistance under the harsh environmental conditions that it will experience; specifically, in terms of sensor and data acquisition integrity and reliability.

2.0 VEHICLE DESCRIPTION

Figure 1 shows a diagramatic representation of the trailer. The vehicle weighs approximately 2.3 tonnes when the ballast tanks are empty and can range up to 4.5 tonnes when the tanks are filled. The running gear consists of an industrial grade single axle assembly of square tubular steel construction with a leaf spring suspension. The wheels are Budd style 22.5" x 7.5" equipped with radial tires.

The trailer has standard commercial safety features for highway travel such as heavy duty safety chains and locks (to prevent separation from the towing vehicle) and electric brakes on both wheels which are operated from a power supply on the vehicle. In the event of a breakaway the brakes are automatically activated.

3.0 TRANSDUCERS

The sensor and transducer compliment is made up of a load cell, an inclinometer and two potentiometers. Time measurement is provided by a real time clock in the data acquisition system. The salient features of the transducers are described below. In section 3.4 additional transducers that are likely to be added at some future stage in the development of the trailer are also described.

3.1 DRAW BAR FORCE LOAD CELL

The drawbar consists of a rolled steel extension connected to a load cell which provides a measurement of the force required to pull the trailer. This force is that which is necessary to overcome the resistance of the haulroad and internal frictional resistance due to tire flexing and bearing friction.

The load cell is a Lebow 3173 which has a maximum capacity of 2000 lb. It is excited by a regulated 5 volt DC supply which gives a maximum full scale output of 15 mV. This signal is amplified and filtered before being converted to digital data.

To prevent damage to the load cell from lateral forces it is encased within an extremely rigid cylindrical bearing. This bearing does not affect forces axial to the load cell from being transmitted to the load cell since it is this force that requires measurement. Axial forces that may exceed the load cell capacity are prevented by an enveloping casing which permits only a limited 'stretching' of the load cell. The entire assembly is enclosed in a protective boot to shield it from the elements.

3.2 SUSPENSION POTENTIOMETERS

Two rotary potentiometers are mounted on the underside of the trailer directly above the axle. A pulley cable arrangement connected to the pots and to the axle provide a rough feedback of suspension travel and therefore road roughness.

3.3 VEHICLE GRADE INCLINOMETER

The inclinometer consists of a pendulum connected to a rotary potentiometer. It is mounted on a plate attached to the drawbar next to the load cell assembly. It is housed in a protective enclosure and an adjustment capability is provided for zeroing.

3.4 ADDITIONAL FUTURE SENSORS

To date the only new sensors that have been acquired are two 'Hall effect' sensors that produce a voltage pulse when a magnet passes close to the sensor. These sensors will be attached near to either the wheel or axle of both the towing vehicle and the trailer and the magnets placed on the

wheel or axle. This will provide a measurement of the number of rotations of the wheel in a given time. This data can then be used to calculate the true velocity of the vehicle trailer and the amount of slip between the driving and towed wheels.

An electronic counter will be necessary to record the number of pulses and convert it to an analogue output that the data acquisition system can understand. This facility is not currently available on the present signal conditioning or data acquisition cards. Consequently it has been decided to upgrade the system by purchasing the latest data acquisition card that the Taurus company provides which has counters mounted upon it.

4.0 SIGNAL CONDITIONING AND SAMPLING

The only transducer with an amplified output is the load cell which produces 15 mV at full scale. To make good use of the 5 volt analog input range of the analog to digital conversion card requires a gain or amplification of 300 times.

Both the amplified load cell signal and the output from the inclinometer are each filtered with a three pole low pass active filter. The cut off frequency is 0.5 Hz to keep the aliasing error below one percent, assuming a sample frequency of 2 Hz. These frequencies may be increased if the data acquisition program can accommodate a higher sampling rate.

The two string pot signals are summed together, and the result divided by two using analogue circuitry. This combined signal is then converted to an RMS equivalent and filtered with the same 0.5 Hz filter as used for the other transducers.

The analogue signal conditioning card is connected to the analog to digital card via a cable which allows the signals to be monitored with a strip chart or DVM and provides a means to bypass the filtering altogether.

5.0 DATA ACQUISITION SYSTEM CONTROL

The data acquisition control system consists of an IBM clone with a commercial (Taurus) data acquisition card that slots into one of the

expansion ports. The software to run the system is also provided by the Taurus company as part of a complete package with the custom data acquisition card.

5.1 HARDWARE

The data acquisition hardware consists of the computer, a signal conditioning card and a data acquisition card. Both of these cards reside within the computer connected to expansion ports.

The computer is an IBM compatible clone with a monochrome graphical monitor. This is possibly the most standard and relatively inexpensive computer of its class. The reasons for selecting this type of computer are that it is very popular having a very wide market and also because the internal architecture of the machine has become a standard to which numerous software and hardware distributors subscribe to. An example of one such subscriber is the Taurus company which produces data interface cards and software exclusively for this computer.

The signal conditioning card was provided by the manufacturer of the trailer (Davis Engineering). Unfortunately the specifications provided to Davis are nov seen to be inadequate and therefore future signal conditioning equipment will be necessary. One of the drawbacks of the conditioning card is that the filters that where provided to reduce noise, also smooth the data to such and extent that rapid changes in data values are not seen. For some applications (such as suspension vibration, which indicates road roughness), it is nov becoming apparent that rapid changes it data values must be recorded. Consequently the signal conditioning card must be altered. In viev of the fact that the signal conditioning must be changed it is desirable to obtain individual signal conditioning units that each control one channel of information. This is because to reconfigure a signal conditioning card that controls numerous channels of information requires detailed knovledge of the card architecture and some electronic engineering experience. With individual signal conditioning units it is an easy operation to alter parameters such as the gain and filtering and to reconfigure the system as desired. Hence future conditioning should be preferably of the individual rack mounted type.

The 'Taurus' data acquisition card has operated according to its specifications without malfunction. However, as described earlier, it has no provision to count electrical pulses. This may be corrected by purchasing individual counters or acquiring the upgraded version of the Taurus data acquisition board that has in-built counters. The cheapest option is to buy the new Taurus card and there is also an advantage in that the card is hidden in the computer and will not occupy additional space in the trailer towing vehicle.

5.2 SOFTWARE

The data acquisition software was provided as part of the Taurus package. Initial investigations show that the software, as it stands at the moment is far to slow. The reasons for this is that the software is written in interpreted Basic. The fact that it written in an interpreted language means that each statement in the program is recovered one at a time by the computer. After each statement has been recovered the 'interpreter' decodes the statement into machine language that the computer can understand. The machine code instructions are then executed and the next program statement is then recovered and the process is repeated.

One of the ways that were considered to improve the speed of data gathering of the system was to write the software that runs the system in a language that can be compiled. With a compiled language all the program statements are converted into machine language before the program is run. This means that the process is not constantly being interrupted so that the computer can translate each statement into machine language.

The Taurus company is in the process of testing a compiled version of their Basic program, but until it has been proven to be reliable it will not be available for distribution. Consequently CANMET has undertaken to write their own compiled system operating program. The language of choice was 'turbo Pascal' which is a high level language which enables a very structured program to be produced. To date the venture has proved to be very successful and has increased data acquisition speed by a factor many times greater that the original software and now exceeds the forseeable requirements of the system.

6.0 ADDITIONAL EQUIPMENT

In addition to the rolling resistance measuring vehicle other instrumentation has been obtained that will provide information related to rolling resistance measurements. These include a 25 tonne capacity load cell and hooks that will give a direct reading of the force required to tow a mine haulage truck. This will provide data for correlating the rolling resistance trailer measurements to the individual types of haulage trucks. This instrumentation is complete with it's own data acquisition system, power supply and signal conditioning. Also, there will be a number of soil strength instruments including, a cone penetrometer and a portable Californian Bearing Ratio (CBR) testing apparatus. In addition to soil strength, a probe capable of measuring soil density and moisture content using two radio active sources will supply a complete picture of haul road conditions.

7.0 TESTING PROCEDURES

7.1 CALIBRATION

The load cell and inclinometer that are installed on the rolling resistance trailer have a greater accuracy than necessary. However, proving rings are available to insure, by periodic checks that the load cell remains in calibration. A simple arrangement of a large accurate protractor and a plumb line temporarily attached to the inclinometer will provide a rapid and accurate method of ensuring the correct functioning of the sensor.

The 25 ton load cell that will be used for direct measurement of the force required to tow one truck with another is known to be a very stable sensor, as is the load cell used in the tow bar of the trailer. Hence drift in zeroing or span is expected to be negligible. For the sake of satisfying confidence in the cell, measuring instrumentation and conditioning, the 25 ton load cell has been directly compared to another load cell of similar capacity at the University of Edmonton. Very close agreement between the two instruments was obtained.

7.2 FIELD TRIALS

The subject of the intended field trials is extensive enough to warrant a report of its own. Consequently only a brief description is provided here and additional information will be provided in a following paper.

The initial field trials will obviously be devoted to ensuring that the instrumentation is functioning correctly and that the data produced by this instrumentation is recorded at the desired rate and correct format.

Possibly the best method of testing the quality of the instrumentation, and indeed the suitability of the entire approach to measuring rolling resistance using a trailer, will be to measure the parameters of rolling resistance, grade, roughness etc, of a specific section of road a number of times and compare the repeatability of the data. If this is done on a number of roadway conditions and the results are as expected and also repeatable, then a high degree of confidence in the proposed methodolgy can be justified.

In conjunction with the trailer field trials, the road conditions will be directly measured using a variety of instrumentation packages. The term 'road conditions' is used in this context to indicate soil strength, density, moisture content etc. The instrumentation packages to date, include, a portable Californian Bearing Ratio laboratory and a cone penetrometer for determining soil strength and a MC-3 Portaprobe which utilizes both a gamma and neutron source for determining moisture content and density. The primary reason for using these instruments will be to gain familiarity with their use, though the data produced will be of interest when assessed with the rolling resistance data.

8.0 CONCLUSIONS

The rolling resistance program is proceding on schedule and the trailer is due to commence field trials within a few weeks. Additional sensors, signal conditioning and data acquisition cards will be added as soon as they are acquired in order to continually improve the performance of the system.

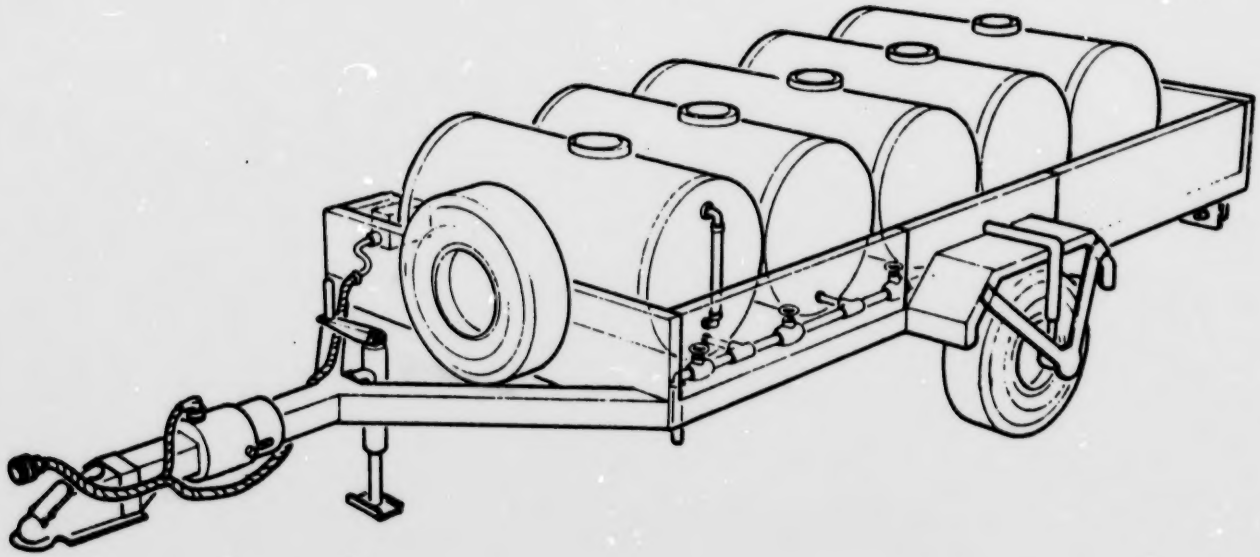

Fig. 1 - Rolling Resistance Trailer